

The Research of Wind- thermal Power Random Multi-objective Scheduling Based on Combined MIPSO

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Abstract

There are strong randomness in wind power, its output is not controllable. Large scale wind power grid-connection to dispatch system brings new uncertainty. This paper constructs the wind-fire random optimal model based on combined MIPSO algorithm and achieves the multi-objective optimizations on the minimization of power cost and pollution emissions of thermal power units. Firstly, wind power outputs can be forecasted by utilizing BP neural network algorithm. Then random multi-objective optimal solution is obtained through MIPSO algorithm. Finally, multi-objective optimal scheduling is illustrated by using the IEEE-30 node. The results show that the combination arithmetic solution set uniform distribution, predict accuracy and qualified rate were 0.9962 and 0.7651, using MIPSO algorithm is out of the solution of the highest degree of coordination, get each time specific unit output of the plan, according to the calculation results make corresponding power generation plan, to access a fairly large wind power dispatch system has the actual reference value, so the proposed method is feasible and effective.

Keywords: *wind power grid-connection; system scheduling; multi-objective optimization; BP - MIPSO algorithm; coordination degree; random optimal model*

1. Introduction

Electricity is a kind of extremely clean energy, but in the use of the energy have the negative effects on the environment. In the global energy crisis and environmental pollution background, the electric power industry must start promoting energy conservation and environmental protection of power generation scheduling new mode [1].

New scheduling model should first consider the full use of renewable energy to power generation, and to consider operation performance of thermal power units and environmental protection, this puts forward new requirements for only consider the economy target scheduling optimization strategy [2]. Across the region and national borders interconnected power grids, as well as all kinds of regional distribution of a wide range of renewable clean energy, unit also puts forward the new challenges of the past to central control mode of electric power [3].

At present, our country still with thermal power is given priority to, thermal power units are more than 70% of capacity totally, in the future for a long time still can't change the condition, therefore, consider the clean energy and firepower unit united cooperation is a kind of practical needs. Energy saving power is the dispatch according to the energy saving, environmental protection, economy of the principles of power dispatch under the premise of

reliable power supply. Priority to scheduling wind energy, water, biomass energy and other renewable power generation resources, then scheduling coal and power resources [4]. In the specific scheduling, press unit as pollutant emission or energy consumption level from low to high arrangement online, minimize resource consumption and pollution emission. Compared with the traditional dispatching, energy saving dispatching is more attention to energy conservation and environmental protection; reduce the unit in the production of electric energy emphasis on pollutants; tend more to schedule the renewable energy units and large environmental fire unit efficiency. Thus, which saves energy, reduces the pollution of the environment, and realize the sustainable development of the power industry [5].

2. The Wind-thermal Power Dispatching Multi-objective Mathematical Model

Where there is great love, there are always miracles. Love is like a butterfly. It goes where it pleases and it pleases where it goes. If I had a single flower for every time I think about you, I could walk forever in my garden. Within you I lose myself, without you I find myself wanting to be lost again. At the touch of love everyone becomes a poet.

2.1. The Objective function

(1) Economic goals

First consider the system of the unit cost of conventional fire power generation minimization (ignore the wind power generating cost)

$$f = \min \sum_{t=1}^T \sum_{i=1}^{Ns} [U_{it} F_i(P_{it}) + U_{it}(1 - U_{it-1}) S_i] J \quad (1)$$

where t is time, T is the calculation of the biggest number, i is the label of thermal power unit, Ns is the number of thermal power unit; U_{it} is the variables of first unit during the t time interval, $U_{it} = 0$ means downtime, $U_{it} = 1$ means operation; P_{it} is the output of t time of no. i unit; $F(P_{it})$ is the power cost of t time of no. i unit. It can fitting using the second curve.

$$F(P_{it}) = a_i + b_i P_{it} + c_i P_{it}^2$$

a_i, b_i, c_i are thermal power generating cost coefficient respectively, S_i is thermal power unit start-up costs.

Conventional thermal power unit output can control, so is deterministic variables, its power cost is also certain amount; Suppose Output of the balance unit is fluctuant randomly, so the balance of the unit output is random variables, the cost is also random amount, the total system power cost become random amount, therefore, formula 1 can be written as:

$$f_1 = \min \sum_{t=1}^T \left\{ \sum_{i=1}^{Ns-Nk} [U_{it} F_i(P_{it}) + U_{it}(1 - U_{it-1}) S_i] + \sum_{k=1}^{Nk} (F_k(\tilde{P}_{kt})) \right\} \quad (2)$$

Where N_k is the balance of the number of units with the wind power on active mediation.

Because the randomness of the wind power output, The active output of balance should be is random unit, so economy has become the random objective function[6].

(2) The Environmental protection goal

Considering all the balance of the pollution to get the minimum unit discharge, have the formula:

$$f_2 = \min \sum_{t=1}^T \sum_{i=1}^{Ns-Nk} [\alpha_i + \beta_i P_{it} + \gamma_i P_{it}^2 + \eta_i \exp(\delta_i P_{it})] \quad (3)$$

Where $\alpha_i, \beta_i, \gamma_i, \eta_i, \delta_i$ are the thermal power unit pollution emission coefficient respectively.

2.2. Constraint conditions

(1) System active balance constraint

$$P_{Dt} = P_{Gt} + \tilde{P}_{Gt} - P_{Lt} \quad (t \in T) \quad (4)$$

(2) Spinning reserve constraint

Because the randomness of the wind power output, spinning reserve equipment must be considered for a fairly large wind power system. Wind power can't provide spinning reserve, so total spinning reserve is the sum of all except outside unit can provide:

$$\begin{cases} R^{up} = \sum_{i=1}^{Ns} (P_i^u - P_{Gi}) \\ R^{dn} = \sum_{i=1}^{Ns} (P_{Gi} - P_i^l) \end{cases} \quad (5)$$

(3) Thermal power unit output upper and lower constraint

$$P_i^{\min} \leq P_{it} \leq P_i^{\max}, \quad i \in N_s, \quad t \in T \quad (6)$$

Where P_i^{\min}, P_i^{\max} are the minimum and the maximum thermal power output unit limits.

(4) Lines active power constraint

The line (endpoint) of the active power flow can be written as

$$F_{l,s} = \frac{\theta_{ij}}{x_{ij}} = \frac{M_l \cdot X}{x_{ij}} \Delta P_l \quad (7)$$

Where θ_{ij} is phase difference of branch l , M_l is a node-line relating matrix; X is the circuit reactance matrix, x_{ij} is the line $i - j$'s circuit reactance; $F_{l,s}$ is the Active power flow in t time. ΔP_l is the active injective power.

Lines active power constraint is below:

$$F_l^{\min} \leq \frac{M_l \cdot X}{x_{ij}} \Delta P_l \leq F_l^{\max} \quad (8)$$

Where F_l^{\min} , F_l^{\max} representative lower and upper limit of active power lines.

(5) Thermal power unit response rate constraint

For thermal power unit, the next time load must be based on the output of last time, so consider the more time thermal power unit scheduling must consider its output response rate. thermal power unit response rate is called add and subtract load rate:

$$-\gamma_i \Delta t \leq P_{i,s} - P_{i,s-1} \leq \gamma_i \Delta t \tag{9}$$

Where γ_i is the rate of add and subtract load, $\gamma_i \Delta t$ is the maximum of every time can output[7].

(6) System climbing capacity constraints

In order to correspond fluctuate need other system unit has the fast enough response speed, that is climbing capacity requirements. The sum of the system in thermal power unit climbing ability must be greater than the fluctuation of rate of the output was able to sustain the wind power disturbances, therefore, the system climbing ability also mark the maximum wind power capacity system could be used to:

$$\sum_{i=1}^{Ns} \gamma_i P_{it} \geq \sum_{j=1}^{Nw} \delta_j P_{jt} \tag{10}$$

Where γ_i is the conventional thermal power unit output rate of change, δ_j is the wind generator j the possible maximum output rate.

(7) The system frequency offset constraint

Because of the output of the wind is fluctuant randomly, the system of active power fluctuations inevitably, it leads to the static frequency offset, we can get the static frequency characteristic expression according to the power system:

$$\Delta f = \Delta P / K_s \tag{11}$$

Among them $K_s = (\rho K_G + K_D)$ is the frequency of the system static characteristic coefficient, ρ is the ratio of the initial power and the total load power with the imbalance moment; K_G is the average slope of system generator mover frequency of static properties, if not full load, the frequency coefficient of thermal power unit static properties generally is between 16.7-25, if full load unit, the value is 0; K_D is the frequency mediation coefficient of the static properties, the value range is from 1.0 to 3.0. The value of K_G, K_D as a benchmark of the system initial moment load, Δf_t is to show the steady-state frequency offset t time, ΔP_t is the value of the active power system out of balance, the following formulation as shown:

$$\Delta P_t = \sum_{i=1}^{Ns-Nk} P_{it} + \sum_{i=1}^{Nk} \tilde{P}_{it} + \sum_{j=1}^{Nw} \tilde{P}_{jt} - P_{Dt} - P_{Lt} = P_{Gt} + \tilde{P}_{Gt} - P_{Dt} - P_{Lt} \quad (t \in T) \tag{12}$$

$$\Delta f_t = \frac{(P_{Gt} + \tilde{P}_{Gt} - P_{Dt} - P_{Lt})}{(\rho K_G + K_D)} \quad (t \in T) \quad (13)$$

Where N_w is the wind generator, \tilde{P}_{jt} is the output in t time of generator, j is a random value, P_{Dt} is the system load in t time, P_{Lt} is the network loss in the t time of system, P_{Gt} is the output of fixed type generator unit during the t time, \tilde{P}_{Gt} is the output of unfixed type in t time[8]:

$$f' - f_0 \leq \Delta f_1 \leq f'' - f_0 \quad (14)$$

Will the objective function to form expectations, constraint condition to form probability, the wind- thermal multi-objective scheduling model are formula (1)-(14).

3. BP Combined with Immune Particle Swarm Algorithm

The randomness of the wind is very strong and basically not controllable, wind output depends on wind speed, and the wind speed is not governed by man's will as the shift. At the same time the wind speed is influenced by multiple factors, such as temperature, humidity, terrain, atmospheric pressure, *etc.*, and the coupling between multiple factors, influencing the accuracy of prediction [9].

In this article, the BP neural network algorithm combined with the physical characteristics of wind turbine operation parameters, select the appropriate input parameters, improve the prediction precision. Multi-objective immune particle swarm algorithm to solve target model, which is a combination bp- MIPSO realize the wind-thermal power random multi-objective scheduling, obtains each time more close to the actual situation of the power generation plan, to access a fairly large wind power system scheduling plan has practical reference significance.

3.1. The structure of the BP neural network

This paper forecast the future 24 hours wind power, so the number of output layer is determined for three.

Input parameter is critical to the neural network. We can use the wind speed of several hours ago, wind direction, wind power and time, *etc.* [10].

Through comparative study found that using history power as the input and with wind speed, wind direction, time and so on factors as input, prediction accuracy has difference. Historical power input of the prediction error is small, this is because the wind speed, wind direction, time does not include the status of the generator unit' information. In order to improve the prediction accuracy, we use the history power and the wind speed, wind direction, *etc* as inputs. Then we found the improvement of accuracy is very limited. This is because with the increase of input parameters, the network structure becomes complex and difficult training and optimization. Through analysis shows that can obtain the highest prediction accuracy when we select the history data and wind speed as input parameters.

3.2 BP- -MIPSO algorithm steps

So based on bp-MIPSO optimization steps are below:

- 1、 Input network/unit parameters, and generate the node-line relating matrix M_i and the circuit reactance matrix X ;
- 2、 Input the Wind power forecasting and prediction error function;
- 3、 Input particle swarm parameters, the biggest algebra, population size, etc;
- 4、 Set calculation time $t = 1$;
- 5、 Set random simulation counter $p = 1$;
- 6、 Simulate the wind power error randomly and correct predictive value;
- 7、 Generate particle swarm, initialize particle position and speed randomly;
- 8、 Calculate the particle fitness, set gbest to the memory particles;
- 9、 Immune clone and update, then create the new particles
- 10、 Inspect whether each particle meets the constraints, if meet, turn step 12;
- 11、 If don't meet the constraints, use memory particles to replace the particles
- 12、 Inspect whether the population diversity meets the threshold value, if meet, turn step 14;
- 13、 if the diversity does not meet the requirements, operate the immune adjustment;
- 14、 Undertake the immune inoculation operation and to generate the new particle;
- 15、 Particle swarm algebra + 1, if not the largest algebra, turn steps 8;
- 16、 If has the largest algebra, judge whether $P + 1$ already to its maximum, if not, turn steps 6;
- 17、 If P has to maximum, judge whether t already to the largest t , if not, turn step 5;
- 18、 If t have to maximum T , output the calculation results, over.

4. Example and Analysis

This paper analysis the system simulation based on the IEEE-30 nodes. Set the wind speed obey Weibull distribution, $k = 2.15$, $c = 8.30$, the wind speed is 15 m/s, the rated capacity of 60 MW, the rated wind is 13 m/s, cut into wind speed is 3 m/s, cut out wind speed is 20 m/s. At the same time put particle swarm scale is 100, cloning scale is 200, maximum iterative times are 150, the weight factor $c_1 = c_2 = 2.05$, the assumption of wind power grid node for 9 nodes, conventional unit 1 is the balance units, and the other five regular units for the optimization of the output to variable.

IEEE-30 nodes B coefficient matrix of the system are as follows [11]:

$$\begin{bmatrix} 0.1382 & -0.0299 & 0.0044 & -0.0022 & -0.0010 & -0.0008 \\ -0.0299 & 0.0487 & -0.0025 & 0.0004 & 0.0016 & 0.0041 \\ 0.0044 & -0.0025 & 0.0182 & -0.0070 & -0.0066 & -0.0066 \\ -0.0022 & 0.0004 & -0.0070 & 0.0137 & 0.0050 & 0.0033 \\ -0.0010 & 0.0016 & -0.0066 & 0.0050 & 0.0190 & 0.0005 \\ -0.0008 & 0.0041 & -0.0066 & 0.0033 & 0.0005 & 0.0244 \end{bmatrix}$$

In this paper, the wind-thermal power system was simulated considering wind power prediction error and wind power load forecasting, the results are as follows:

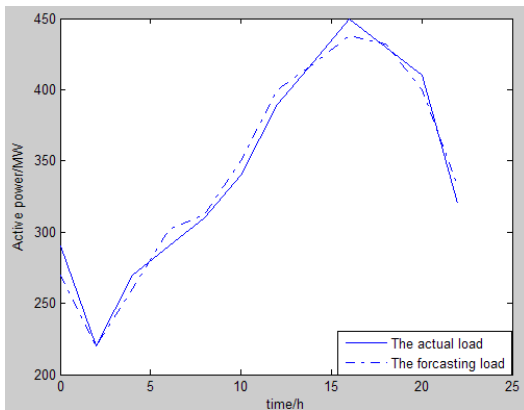


Figure 1. System Prediction and actual load curve

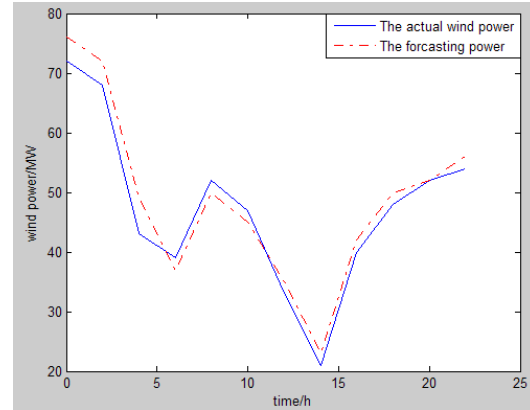


Figure 2. Prediction and actual wind power curve

Table 1. The results calculation considering the wind power prediction and load forecasting error

cost (\$)	Pollution emissions (ton)	Coordination degree	Non-inferior solution Numbers
17914.32	5.5159	0.024103	X1
17936.29	5.5893	0.025500	X2
17943.00	5.5183	0.027169	X3
17924.23	5.4329	0.028613	X4
17950.01	5.4121	0.030116	X5
17974.26	5.3549	0.031005	X6
17915.27	5.3021	0.032310	X7
17925.10	5.2561	0.033115	X8
17980.00	5.2101	0.030295	X9
18001.12	5.1763	0.034572	X10
18023.01	5.1229	0.035341	X11
18147.89	5.0521	0.036695	X12
18132.26	5.0449	0.037054	X13
18253.10	5.0112	0.038357	X14
18323.59	4.9782	0.037625	X15
18395.87	4.9360	0.037411	X16
18315.01	4.9012	0.035215	X17
18655.12	4.8901	0.038241	X18
18823.95	4.8584	0.033921	X19
18748.26	4.8487	0.038071	X20

19001.14	4.8521	0.037214	X21
19034.10	4.8240	0.037002	X22
19105.00	4.8057	0.036421	X23
19235.12	4.7956	0.035011	X24
19425.01	4.7979	0.033254	X25
19589.15	4.7947	0.030924	X26
19674.01	4.7881	0.029525	X27
19877.00	4.7856	0.027948	X28
20153.98	4.7900	0.025762	X29
20215.26	4.7874	0.024011	X30

From Table 1, we can know that the X14 non-inferior solution the coordination degree is the highest, about 0.038357, X14 each period of the output of generating unit as shown in Table 2.

Table 2. The results of X14 non-inferior solution in each period of the output of generating unit

time	P1(MW)	P2(MW)	P3(MW)	P4(MW)	P5(MW)	P6(MW)
1	25.69	30.05	39.25	39.14	33.19	24.15
2	23.52	27.41	33.03	33.16	30.52	22.13
3	28.47	31.50	35.14	36.24	34.06	25.09
4	32.15	35.00	38.01	38.51	35.17	27.14
5	38.15	40.01	43.26	44.12	40.59	32.06
6	41.12	43.25	45.01	45.07	45.18	31.24
7	44.24	43.14	47.96	47.18	44.08	32.01
8	52.42	51.03	53.14	53.26	52.17	40.16
9	54.04	51.12	55.16	55.14	53.06	40.03
10	60.21	58.07	60.47	61.02	58.49	43.21
11	69.03	65.21	70.49	70.58	66.47	50.02
12	78.95	76.12	76.02	75.19	65.12	51.19
13	79.26	79.58	70.13	70.05	73.16	57.04
14	78.24	75.95	65.00	64.39	68.48	52.99
15	81.87	79.52	66.49	66.54	67.24	48.31
16	77.16	76.03	61.95	62.30	60.15	44.25
17	84.02	82.19	70.17	69.09	68.09	50.02
18	86.27	85.24	72.59	72.16	63.27	48.98
19	82.53	76.49	69.85	69.05	55.13	42.16
20	75.17	68.92	60.44	58.46	45.24	33.27
21	65.07	64.04	50.17	50.19	39.46	25.59
22	59.59	57.21	48.27	48.79	33.19	22.18
23	58.96	53.73	45.18	45.02	34.01	21.97
24	55.08	51.09	40.05	40.59	32.42	22.05

5. The Results Discussed

(1) Predicting error analysis[12]

On the prediction error, we use the accuracy and the percent to analysis accuracy :

$$r_1 = \left(1 - \sqrt{\frac{1}{N} \sum_{k=1}^N \left(\frac{P_{MK} - P_{pk}}{Cap} \right)^2} \right) \times 100\% \quad (15)$$

Qualified rate:

$$r_2 = \frac{1}{N} \sum_{k=1}^N B_k \times 100\% \quad (16)$$

Among them:

$$\begin{cases} (1 - \frac{P_{MK} - P_{pk}}{Cap}) \geq 0.75, & B_k = 1 \\ (1 - \frac{P_{MK} - P_{pk}}{Cap}) < 0.75, & B_k = 0 \end{cases}$$

According to the (formula 15) and (formula 16) get wind power prediction accuracy is 0.9962 and qualified rate is 0.7651.

(2) The optimal solution discussion

Through the immune particle swarm algorithm to get harmony degree of the highest non-inferior solution, according to the pareto solutions can get the output value of time. In the actual power dispatch which access to large scale of wind power, because the randomness of the output need to deal with the fluctuation of output, increases the spare capacity [13]. At this time, thermal power unit cannot complete according to its power cost and pollution emissions for the optimal scheduling and must be properly consider its spare capacity increase. In considering the wind power predicting error of the scheduling plan, the result already contained the randomness of the wind power influence, will more close to the wind-the actual status of the thermal power dispatching, to the actual scheduling plan more realistic reference value.

6. Conclusion

This paper combines BP neural network with MIPSO algorithm to solve the wind-multi-objective scheduling problem thermal power. Wind power and load is two more random factors in power system, BP neural network considering the satue of generator unit and Meteorological factors to improve the wind power prediction accuracy. Based on wind power prediction, and calculates the coordination of the solution of the highest degree, get each time specific unit output of the plan, to the actual **operation has good practical value**.

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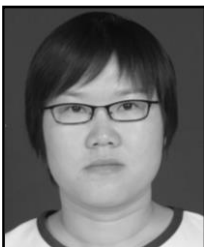
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